ICC Docket No. 16-0376

Direct Testimony of Allen Neale

AG Exhibit 1.3

Index of Attached Discovery Responses

AG 4.05
AG 4.12 and AG 4.12 Supplement
AG 4.12 Attach 01 PDF
AG 7.06
AG 7.07
AG 7.08
AG 7.09
AG 11.09
AG 11.17
AG 11.10
AG 11.11
AG 11.12
AG 11.13
AG 11.14
ENG 1.01
ENG 1.01 attachment 01
AG 11.18
AG 6.06
AG 4.17
AG 11.03
AG 11.07
AG 11.08
AG 4.01

The Peoples Gas Light and Coke Company
Docket No. 16-0376
Response to the Illinois Attorney General's 4th Set of Data Requests
Date of Requests: August 26, 2016

REQUEST NO. AG 4.05:

Please refer to the Direct Testimony of Mr. Hesselbach, PGL Ex. 1.0, p. 21, lines 413-414, that states: "Peoples Gas has a neighborhood ranking system that uses several key metrics" and respond to the following questions:

a) Please provide a complete copy of the "neighborhood ranking system," including all supporting manuals and guidelines.
b) Please list all "metrics".
c) Please define all "metrics" in complete detail.
d) For each listed "metric" identify the numerical weight assigned to each.
e) Please describe how the borders of the "neighborhoods" are determined by the Company in the "neighborhood ranking system."
f) Provide a complete rank ordered list of each "neighborhood" in the Company's service territory with the associated score in the ranking system.

RESPONSE:

a) Please see attachment AG 4.05 Attach 01 as well as the responses to AG 1.06 and CUB 2.03.

b) % of CIDI Medium Pressure Pipe, % of CI Main <=8", Mean MRI, % of Vulnerable Services, Total Pending Leaks (2 & 3) per mile of main.

c)

i. "% of CIDI medium pressure pipe" is the amount of cast iron and ductile iron gas mains operating at medium pressure within that neighborhood divided by the total amount of low pressure gas main and medium pressure cast and ductile iron mains.
ii. "% of CI Main <=8" is the total amount of cast iron main that is 8 inch in diameter or smaller within that neighborhood, divided by the total amount of low pressure gas main and medium pressure cast and ductile iron mains.
iii. "Mean MRI" is the statistical mean of all the segments of low pressure gas main and medium pressure cast and ductile iron gas mains within a neighborhood.
iv. "% of Vulnerable services" is the number of service pipes made of vulnerable material types (cast iron, ductile iron, copper, clear plastic, bare

steel) divided by the total number of service pipes to be replaced within that neighborhood.

i. "Total Pending Leaks (2 & 3) per mile of main" is the total number of pending leaks taken at the time of the annual model which are class 2 and 3 leaks, divided by the total amount of mains in the neighborhood.

d)

i. % of CIDI Medium Pressure Pipe – 30%
ii. % of CI Main <=8" – 15%
iii. Mean MRI – 30%
iv. % of Vulnerable Services – 15%
v. Total Pending Leaks (2 & 3) per mile of main – 10%.

e) The neighborhood boundaries are created using the City of Chicago neighborhood boundaries.

f) Please refer to AG 1.06 Attach 01.

Person(s) Responsible:

Mark Kinzle – Director, Gas Operations Planning

Construction Planning Procedure

PEOPLES GAS
NATURAL GAS DELIVERY

Procedure Number		Date	01/21/2016
Procedure Name:	**Neighborhood Ranking**		

Procedure Description

The following outlines the assumptions and procedure for ranking the 228 neighborhoods within Peoples Gas service territory. The data will be extracted in January and the ranking information will be provided to Director of Gas Planning by January 30th each calendar year. This information will be utilized to identify the 5 year neighborhood main replacement plan.

General Information (Definitions)

AMRP: Accelerated main replacement program

QIP: Qualified Infrastructure Plant

AMRP Main: Miles of main to be replaced per QIP eligibility requirements

AMRP Services: Services to be replaced per QIP eligibility requirements

CI: Cast Iron

CI/DI MP Main: Cast Iron/Ductile Iron medium pressure main

Mean MRI: Mean Main Ranking Index

Vulnerable Services: Service material types that are unprotected bare steel, unprotected coated steel, clear plastic, and copper

Total Pending Leaks: Total number of active Class 2 and Class 3 leaks in a neighborhood

Ranking Analysis

Assumptions:

1. Weighting scale percentages used in the analysis are to be provided by the Director of Gas Operations Planning. For 2015 and 2016 the weighting percentage scales are as follows:

- % of CIDI MP – 30%
- % of CI Main <= 8” – 15%
- Mean MRI – 30%
- % of Vulnerable Services – 15%
- Total Pending Leaks (2 & 3 only) per mile – 10%

GIS Data Query:

2. The Distribution Engineering Department’s Senior GIS Specialist will extract the following information for each of the 228 Chicago neighborhoods utilizing a pre-determined GIS query containing the following data:

Construction Planning Procedure

PEOPLES GAS
NATURAL GAS DELIVERY

Procedure Number		Date	01/21/2016
Procedure Name:	**Neighborhood Ranking**		

- Miles of AMRP main
- Number of AMRP Services
- Miles of CI/DI MP Main
- Miles of CI Main <=8”
- Mean MRI
- Number of Vulnerable Services
- Number of Total Pending Leaks

Preliminary Neighborhood Ranking Analysis:

3. The neighborhood data extracted from the GIS query will be placed in the Neighborhood Ranking Excel worksheet Data Tab (Columns A thru H).
4. Once the data in Step 3 is inserted, Columns I thru R contain formulas to calculate the percentages for the following (4) categories:

- AMRP Mains that are CI/DI MP main
- AMRP Mains that are CI and 8” or smaller
- AMRP Services that are vulnerable
- Number of leaks per mile of AMRP Main.

5. The neighborhoods are ranked for each of the 4 categories with a Ranking of 1(Best) to 228 (Worst).

Final Neighborhood Ranking Analysis:

6. To calculate the final ranking score, the ranking of each category is multiplied by the weight percentage for each category and summed to determine the final ranking score (column I) on the Neighborhood Ranking Excel worksheet Weighting and Scoring Data Tab.
7. Each shop is filtered into their respective tabs with their scores. Please note, neighborhoods may be listed on multiple shop tabs due to the overlap in work boundaries of the shops. Determination as to which shop will execute the overall project will be determined during the 5 year plan analysis.
8. The top 10 ranked neighborhoods for each shop and the combined total are filtered and complied into the Worst 10’s tab.
9. Once reviewed by the Construction Planning Manager, the Neighborhood Ranking Excel spreadsheet is forwarded to the Director of Gas Operations Planning.

References

1. QIP Classification Procedure
- T:\DEPTS\GE_GDDS\Departmental\engdata\1 GAS ENGINEERING SOUTH\8 PROCEDURES\2014 Procedures\QIP Classification Procedure.doc
2. Neighborhood Ranking Process Folder
- T:\DEPTS\GE_Planning\Shared\Construction Planning\! Process\Neighborhood Ranking
3. Neighborhood Ranking Procedure
- T:\DEPTS\GE_Planning\Shared\Construction Planning\! Process\Neighborhood Ranking\Neighborhood Ranking Process 012016.doc
4. Neighborhood Ranking GIS Data

Construction Planning Procedure

PEOPLES GAS
NATURAL GAS DELIVERY

Procedure Number		Date	01/21/2016
Procedure Name:	**Neighborhood Ranking**		

- T:\DEPTS\GE_Planning\Shared\Construction Planning\! Process\Neighborhood Ranking\2016\GIS Data 2016

5. Ranking Model Spreadsheet

- T:\DEPTS\GE_Planning\Shared\Construction Planning\! Process\Neighborhood Ranking\2016\Ranking Model\Neighborhood Ranking.xlsx

Revisions and Approvals	
Date Effective:	
Revision Dates:	
Approved By:	
Location on Shared Drive or Intranet	

REQUEST NO. AG 4.12:

Please refer to the Direct Testimony of Mr. Hesselbach, p. 27, Figure 2, and respond to the following:

a) Provide the data used to create the chart in working Excel format with all rows and column labeled and identified.
b) Does the leak data represent leaks repaired by year or leaks found by year on the system by leak survey?
c) Describe how the data was weather-normalized and provide all workpapers, calculations, and assumptions used to normalize the data, in working Excel format.
d) Identify the types of main that went into miles of main figure used to calculate the leaks found ratio for each year in the chart.
e) For each year from 2010 to 2015, provide the total number of miles of main by pipe material type in the Company's distribution system. Provide your answer in working Excel format.
f) Identify separately number of priority Type 1 and 2 leaks that went into the leaks found figure used to calculate the leaks found ratio for each year in the chart. For each grade of leak identified (Type 1, Type 2, etc.) please explain with reasonable specificity each definition.
g) For each year from 2010 to 2015, provide the total number of leaks found per year by surveys and by leak priority (if known).
h) For 2010 to 2015, discuss any changes to the definition of leak grades used by the company and the number of leaks regraded by year.
i) For 2010 to 2015, discuss with reasonable specificity the company's leak survey program.
j) For each year from 2010 to 2015, identify by year:
    i. The types of leak surveys conducted, along with an explanation of the advantages and disadvantages of each survey type.
    ii. The number of each type of survey conducted.
    iii. The month(s) of the year each different survey was performed.
    iv. The percentage of the distribution system covered by each survey.
    v. The leaks found by each type of leak survey conducted.
k) Provide the section of the Company's O&M manual governing leaks surveys, and explain with reasonable specificity any deviation between the requirements of the manual and the actual leak surveys conduct.

RESPONSE:

a) See **AG 4.12 Attach 01**.

b) The leak data is every classification and re-classification of a leak regardless of its current status.

c) See **AG 4.12 Attach 02**. The leaks were weather normalized based on Heating Degree Days (HDD) and the percentage warmer and/or colder that the winter months were compared to average. The average percent warmer or colder of the months November through March was applied across the whole year's leak data to reduce or increase the leak count to a number that would be expected during average temperatures.

d) Miles of main is not used in the calculation.

e) See **AG 4.12 Attach 03**

f) See **AG 4.12 Attach 01** and **AG 4.12 Attach 04**

g) Peoples Gas objects to this request as asking it to create a study or analysis that does not exist.

h) There have been no changes to Peoples Gas' leak classification guidelines from 2010-2015. Peoples Gas objects to the request of the quantity of all leak regrading as asking it to create a study or analysis that does not exist.

i) See **AG 4.12 Attach 05**.
   i. Peoples Gas does not capture the type of equipment for each survey. As such, it has not done a comparison of different survey types. Peoples Gas follows industry standards and USDOT guidelines. See **AG 4.12 Attach 05**.
   ii. See **AG 4.12 Attach 05** for various survey procedures.
   iii. Peoples Gas objects to this request as asking it to create a study or analysis that does not exist.
   iv. Peoples Gas objects to this request as asking it to create a study or analysis that does not exist.
   v. Peoples Gas objects to this request as asking it to create a study or analysis that does not exist.

j) Peoples Gas objects to this request as asking it to create a study or analysis that does not exist. See **AG 4.12 Attach 05**.

Person(s) Responsible:

Mark Kinzle – Director, Gas Operations Planning

REQUEST NO. AG 4.12:

Please refer to the Direct Testimony of Mr. Hesselbach, p. 27, Figure 2, and respond to the following:

a) Provide the data used to create the chart in working Excel format with all rows and column labeled and identified.
b) Does the leak data represent leaks repaired by year or leaks found by year on the system by leak survey?
c) Describe how the data was weather-normalized and provide all workpapers, calculations, and assumptions used to normalize the data, in working Excel format.
d) Identify the types of main that went into miles of main figure used to calculate the leaks found ratio for each year in the chart.
e) For each year from 2010 to 2015, provide the total number of miles of main by pipe material type in the Company's distribution system. Provide your answer in working Excel format.
f) Identify separately number of priority Type 1 and 2 leaks that went into the leaks found figure used to calculate the leaks found ratio for each year in the chart. For each grade of leak identified (Type 1, Type 2, etc.) please explain with reasonable specificity each definition.
g) For each year from 2010 to 2015, provide the total number of leaks found per year by surveys and by leak priority (if known).
h) For 2010 to 2015, discuss any changes to the definition of leak grades used by the company and the number of leaks regraded by year.
i) For 2010 to 2015, discuss with reasonable specificity the company's leak survey program.
j) For each year from 2010 to 2015, identify by year:
    i. The types of leak surveys conducted, along with an explanation of the advantages and disadvantages of each survey type.
    ii. The number of each type of survey conducted.
    iii. The month(s) of the year each different survey was performed.
    iv. The percentage of the distribution system covered by each survey.
    v. The leaks found by each type of leak survey conducted.
k) Provide the section of the Company's O&M manual governing leaks surveys, and explain with reasonable specificity any deviation between the requirements of the manual and the actual leak surveys conduct.

RESPONSE:

a) See **AG 4.12 Attach 01**.

b) The leak data is every classification and re-classification of a leak regardless of its current status.

c) See **AG 4.12 Attach 02**. The leaks were weather normalized based on Heating Degree Days (HDD) and the percentage warmer and/or colder that the winter months were compared to average. The average percent warmer or colder of the months November through March was applied across the whole year's leak data to reduce or increase the leak count to a number that would be expected during average temperatures.

d) Miles of main is not used in the calculation.

e) See **AG 4.12 Attach 03**

f) See **AG 4.12 Attach 01** and **AG 4.12 Attach 04**

g) Peoples Gas objects to this request as asking it to create a study or analysis that does not exist.

h) There have been no changes to Peoples Gas' leak classification guidelines from 2010-2015. Peoples Gas objects to the request of the quantity of all leak regrading as asking it to create a study or analysis that does not exist.

i) **See AG 4.12 Attach 05**.

i. Peoples Gas does not capture the type of equipment for each survey. As such, it has not done a comparison of different survey types. Peoples Gas follows industry standards and USDOT guidelines. See **AG 4.12 Attach 05**.
ii. See **AG 4.12 Attach 05** for various survey procedures.
iii. Peoples Gas objects to this request as asking it to create a study or analysis that does not exist.
iv. Peoples Gas objects to this request as asking it to create a study or analysis that does not exist.
v. Peoples Gas objects to this request as asking it to create a study or analysis that does not exist.

j) Peoples Gas objects to this request as asking it to create a study or analysis that does not exist. See **AG 4.12 Attach 05**.

Person(s) Responsible:

Mark Kinzle – Director, Gas Operations Planning

SUPPLEMENTAL RESPONSE:

In connection with Attorney General Data Request AG 7.04, Peoples Gas is supplementing its response to provide clarification on the labeling of its Responses to subparts (i), (j), and (k).

In response to subpart (i), please refer to **AG 4.12 Attach 01**.

In response to subpart (j):

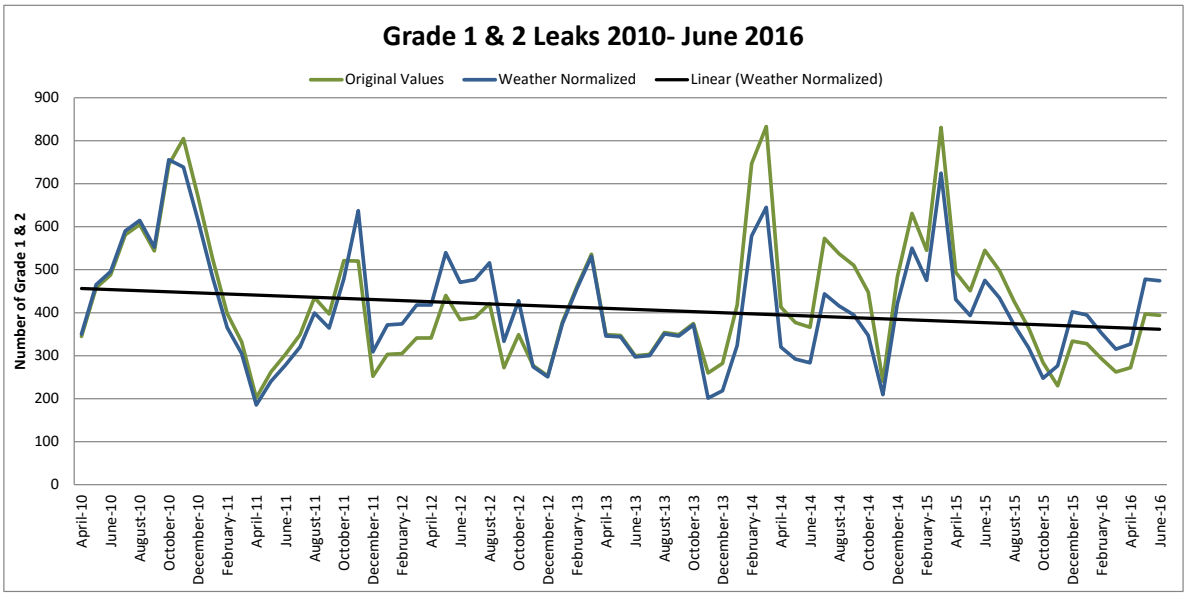
i. Peoples Gas does not capture the type of equipment for each survey. As such, it has not done a comparison of different survey types. Peoples Gas follows industry standards and USDOT guidelines. See **AG 4.12 Attach 05**.
ii. See **AG 4.12 Attach 05** for various survey procedures.
iii. Peoples Gas objects to this request as asking it to create a study or analysis that does not exist.
iv. Peoples Gas objects to this request as asking it to create a study or analysis that does not exist.
v. Peoples Gas objects to this request as asking it to create a study or analysis that does not exist.

In response to subpart (k), Peoples Gas objects to this request as asking it to create a study or analysis that does not exist. See **AG 4.12 Attach 05**.

Person(s) Responsible:

Mark Kinzle -- Director, Gas Operations Planning

	GRADE 1	HITS	GRADE 1-HITS	GRADE 2	% Warmer/Colder	Original Sum of Leaks	Leaks +/-	Normalized Sum of Leaks
April-10	186	60	126	219	-1.59%	345	5.4855	350.4855
May-10	208	49	159	299	-1.59%	458	7.2822	465 2822
June-10	200	54	146	342	-1.59%	488	7.7592	495.7592
July-10	253	49	204	377	-1.59%	581	9.2379	590 2379
August-10	268	52	216	389	-1.59%	605	9.6195	614 6195
September-10	306	77	229	315	-1.59%	544	8.6496	552 6496
October-10	375	68	307	437	-1.59%	744	11.8296	755 8296
November-10	331	75	256	549	8.22%	805	-66.1710	738 8290
December-10	298	34	264	405	8.22%	669	-54.9918	614 0082
January-11	219	35	184	342	8.22%	526	-43.2372	482.7628
February-11	159	35	124	274	8.22%	398	-32.7156	365 2844
March-11	112	45	67	265	8.22%	332	-27.2904	304.7096
April-11	104	57	47	155	8.22%	202	-16.6044	185 3956
May-11	132	69	63	199	8.22%	262	-21.5364	240.4636
June-11	166	81	85	218	8.22%	303	-24.9066	278 0934
July-11	158	66	92	257	8.22%	349	-28.6878	320 3122
August-11	188	107	81	354	8.22%	435	-35.7570	399 2430
September-11	141	72	69	328	8.22%	397	-32.6334	364 3666
October-11	206	70	136	385	8.22%	521	-42.8262	478.1738
November-11	181	60	121	399	-22.61%	520	117.5720	637 5720
December-11	139	72	67	185	-22.61%	252	56.9772	308 9772
January-12	159	47	112	191	-22.61%	303	68.5083	371 5083
February-12	151	60	91	214	-22.61%	305	68.9605	373 9605
March-12	169	78	91	250	-22.61%	341	77.1001	418.1001
April-12	143	68	75	266	-22.61%	341	77.1001	418.1001
May-12	166	63	103	337	-22.61%	440	99.4840	539.4840
June-12	186	91	95	289	-22.61%	384	86.8224	470 8224
July-12	230	141	89	300	-22.61%	389	87.9529	476 9529
August-12	298	175	123	298	-22.61%	421	95.1881	516.1881
September-12	179	109	70	202	-22.61%	272	61.4992	333.4992
October-12	242	142	100	249	-22.61%	349	78.9089	427 9089
November-12	217	123	94	183	0.95%	277	-2.6315	274 3685
December-12	134	59	75	178	0.95%	253	-2.4035	250 5965
January-13	174	44	130	248	0.95%	378	-3.5910	374.4090
February-13	201	53	148	312	0.95%	460	-4.3700	455 6300
March-13	219	84	135	401	0.95%	536	-5.0920	530 9080
April-13	184	94	90	259	0.95%	349	-3.3155	345 6845
May-13	201	97	104	243	0.95%	347	-3.2965	343.7035
June-13	164	102	62	238	0.95%	300	-2.8500	297.1500
July-13	181	111	70	233	0.95%	303	-2.8785	300.1215
August-13	211	122	89	265	0.95%	354	-3.3630	350 6370
September-13	198	93	105	244	0.95%	349	-3.3155	345 6845
October-13	192	99	93	282	0.95%	375	-3.5625	371.4375
November-13	172	86	86	174	22.55%	260	-58.6300	201 3700
December-13	156	58	98	184	22.55%	282	-63.5910	218.4090
January-14	217	39	178	240	22.55%	418	-94.2590	323.7410
February-14	392	65	327	420	22.55%	747	-168.4485	578 5515
March-14	366	59	307	526	22.55%	833	-187.8415	645.1585
April-14	177	78	99	314	22.55%	413	-93.1315	319 8685
May-14	192	96	96	281	22.55%	377	-85.0135	291 9865
June-14	201	102	99	267	22.55%	366	-82.5330	283.4670
July-14	247	112	135	438	22.55%	573	-129.2115	443.7885
August-14	248	121	127	410	22.55%	537	-121.0935	415 9065
September-14	263	115	148	362	22.55%	510	-115.0050	394 9950
October-14	267	141	126	322	22.55%	448	-101.0240	346 9760
November-14	169	91	78	162	12.80%	240	-30.7200	209 2800
December-14	200	80	120	363	12.80%	483	-61.8240	421.1760
January-15	240	48	192	439	12.80%	631	-80.7680	550 2320
February-15	189	36	153	392	12.80%	545	-69.7600	475 2400
March-15	319	68	251	580	12.80%	831	-106.3680	724 6320
April-15	202	75	127	367	12.80%	494	-63.2320	430.7680
May-15	158	55	103	348	12.80%	451	-57.7280	393 2720
June-15	218	81	137	408	12.80%	545	-69.7600	475 2400
July-15	227	84	143	355	12.80%	498	-63.7440	434 2560
August-15	198	84	114	313	12.80%	427	-54.6560	372 3440
September-15	170	73	97	268	12.80%	365	-46.7200	318 2800
October-15	179	95	84	200	12.80%	284	-36.3520	247 6480
November-15	137	65	72	158	-20.34%	230	46.7820	276.7820
December-15	165	68	97	237	-20.34%	334	67.9356	401 9356
January-16	165	57	108	220	-20.34%	328	66.7152	394.7152
February-16	152	62	90	203	-20.34%	293	59.5962	352 5962
March-16	134	72	62	200	-20.34%	262	53.2908	315 2908
April-16	143	59	84	188	-20.34%	272	55.3248	327 3248
May-16	177	59	118	279	-20.34%	397	80.7498	477.7498
June-16	174	75	99	295	-20.34%	394	80.1396	474.1396


Grade 1 & 2 Leaks 2010- June 2016
Original Values
Weather Normalized
Linear (Weather Normalized)
Number of Grade 1 & 2
900
800
700
600
500
400
300
200
100
0
April-10
June-10
August-10
October-10
December-10
February-11
April-11
June-11
August-11
October-11
December-11
February-12
April-12
June-12
August-12
October-12
December-12
February-13
April-13
June-13
August-13
October-13
December-13
February-14
April-14
June-14
August-14
October-14
December-14
February-15
April-15
June-15
August-15
October-15
December-15
February-16
April-16
June-16

REQUEST NO. AG 7.06:

Re: PGL response to data request AG 4.12(j)(ii) (originally mis-labeled by PGL as response to data request AG 4.12(i)(ii)).

AG 4.12 Attachment 05 does not state how many of each type of leak survey was conducted for 2015; additionally, it does not appear to apply to years before 2015. Please state the number of each type of leak survey conducted in each year, 2010 through 2015, or else please explain in detail why PGL is not aware of when it conducted different leak surveys.

RESPONSE:

Peoples Gas objects to this data request as overly broad and unduly burdensome with respect to its request for information from before 2015. Data for periods prior to 2015 has been archived and is therefore not readily accessible, and its retrieval and production would impose a significant burden on the company. Without waiving this objection or its General Objections, Peoples Gas responds as follows: Please refer to AG 7.07 Attach 01, for the detail of the number of miles, services and work requests that have been surveyed by type for 2015.

Person(s) Responsible:

Mark Kinzle -- Director, Gas Operations Planning

REQUEST NO. AG 7.07:

Re: PGL response to data request AG 4.12(j)(iii) (originally mis-labeled by PGL as response to data request AG 4.12(i)(iii)).

For each year 2010-2015, please identify the months of the year when each different type of leak survey was conducted, or else please explain in detail why PGL is not aware of when it conducted different leak surveys.

RESPONSE:

Peoples Gas objects to this data request as overly broad and unduly burdensome with respect to its request for information from before 2015. Data for periods prior to 2015 has been archived and is therefore not readily accessible, and its retrieval and production would impose a significant burden on the company. Without waiving this objection or its General Objections, Peoples Gas responds as follows: Please refer to AG 7.07 Attach 01 for data on 2015 leak survey by month and by type of survey.

Person(s) Responsible:

Mark Kinzle -- Director, Gas Operations Planning

Leak Survey Summary - Completed

Trend By Month

Report Run On: 09/19/2016 1:52 pm

W = # of Work Requests
M = # of Miles
S = # of Services

Crew HQ: CCN,CNO,CSO
Year: 2015

integrys

Survey Type		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Crew HQ: CCN-Chicago Central CH														
SA_BARE_ST - BARE STEEL SURVEY	W	0	0	5	2	20	22	23	22	18	0	0	0	112
	M	0	0	0	0	0	0	0	0	0	0	0	0	2
	S	0	0	29	17	279	247	674	337	216	0	0	0	1799
SA_BT - BRIDGE AND TUNNEL SURVEY	W	0	0	1	0	0	0	1	0	0	1	0	1	4
	M	0	0	1	0	0	0	1	0	0	1	0	1	5
	S	0	0	5	0	0	0	5	0	0	5	0	4	19
SA_BUS_LK - BUSCIMP MAIN SVC SURVEY	W	0	0	17	6	84	41	83	59	79	0	0	0	369
	M	0	0	13	5	57	27	77	70	40	0	0	0	288
	S	0	0	488	225	2237	1053	4936	4383	1529	0	0	0	14851
SA_EXP_PIP - RES EXPOSED PIPING SURVEY	W	0	0	10	7	41	26	36	46	26	0	0	0	192
	M	0	0	0	0	1	1	1	1	1	0	0	0	4
	S	0	0	2285	1504	5472	3682	3299	4370	8742	0	0	0	29354
SA_GATE_SN - GATE STATION	W	0	0	2	0	0	2	0	0	2	0	0	2	8
	M	0	0	2	0	0	2	0	0	2	0	0	2	6
	S	0	0	0	0	0	0	0	0	0	0	0	0	0
SA_HP_M_S - PGL HP MAIN SVC SURVEY	W	0	0	101	0	7	132	0	23	0	78	0	88	429
	M	0	0	40	0	2	52	0	8	0	32	0	35	168
	S	0	0	2	0	0	4	0	0	0	2	0	2	10
SA_LOOP - LOOP SURVEY	W	0	0	0	19	0	0	19	0	1	18	0	0	57
	M	0	0	0	47	0	0	50	0	1	48	0	0	145
	S	0	0	0	1731	0	0	1833	0	1	1820	0	0	5385
SA_MP_SN - MP STATION	W	0	0	2	0	0	2	0	0	2	0	0	2	8
	M	0	0	0	0	0	0	0	0	0	0	0	0	1
	S	0	0	0	0	0	0	0	0	0	0	0	0	0
SA_RES_LK - RES MAIN SVC SURVEY	W	0	0	1	3	11	15	27	11	18	0	0	0	86
	M	0	0	2	14	29	31	40	17	45	0	0	0	179
	S	0	0	344	1076	4263	4661	4938	2656	7086	0	0	0	25024
Totals:	**W**	**0**	**0**	**139**	**37**	**163**	**240**	**189**	**161**	**146**	**97**	**0**	**93**	**1265**
	M	**0**	**0**	**58**	**66**	**90**	**113**	**168**	**95**	**89**	**82**	**0**	**38**	**799**
	S	**0**	**0**	**3153**	**4553**	**12251**	**9647**	**15685**	**11746**	**17574**	**1827**	**0**	**6**	**76442**

Survey Type		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Crew HQ: CNO-Chicago North CH														
SA_BARE_ST - BARE STEEL SURVEY	W	0	0	16	3	18	43	53	29	21	0	0	0	183
	M	0	0	0	0	0	1	1	1	0	0	0	0	4
	S	0	0	207	72	455	679	1176	608	403	0	0	0	3600
SA_BT - BRIDGE AND TUNNEL SURVEY	W	0	0	1	0	0	1	0	0	1	0	0	1	4
	M	0	0	0	0	0	0	0	0	0	0	0	0	2
	S	0	0	2	0	0	2	0	0	2	0	0	2	8
SA_BUS_LK - BUSCIMP MAIN SVC SURVEY	W	0	0	23	41	58	95	117	96	22	0	0	0	452
	M	0	0	25	30	42	52	80	59	9	0	0	0	298
	S	0	0	1296	1663	1902	2403	4469	3434	440	0	0	0	15607
SA_EXP_PIP - RES EXPOSED PIPING SURVEY	W	0	0	21	5	21	51	64	31	27	0	0	0	220
	M	0	0	0	0	0	1	1	1	1	0	0	0	4
	S	0	0	3838	812	5536	7588	10892	5535	4814	0	0	0	39015
SA_GATE_SN - GATE STATION	W	0	0	3	0	0	3	0	0	3	0	0	3	12
	M	0	0	0	0	0	0	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	0	0	0	0	0	0	0
SA_HP_M_S - PGL HP MAIN SVC SURVEY	W	0	0	51	1	21	36	1	50	6	0	0	59	225
	M	0	0	20	1	8	15	1	20	3	0	0	26	94
	S	0	0	0	0	0	0	0	0	0	0	0	0	0
SA_MP_SN - MP STATION	W	0	0	1	0	0	1	0	0	1	0	0	1	4
	M	0	0	0	0	0	0	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	0	0	0	0	0	0	0
SA_OHARE - OHARE MAIN SVC SURVEY	W	0	0	0	0	0	0	0	0	0	0	1	0	1
	M	0	0	0	0	0	0	0	0	0	0	21	0	21
	S	0	0	0	0	0	0	0	0	0	0	98	0	98
SA_RES_LK - RES MAIN SVC SURVEY	W	0	0	3	3	10	35	19	16	4	0	0	0	90
	M	0	0	7	6	26	83	50	43	9	0	0	0	222
	S	0	0	983	839	3685	10365	7558	5643	945	0	0	0	30018
Totals:	**W**	**0**	**0**	**119**	**53**	**128**	**265**	**254**	**222**	**85**	**0**	**1**	**64**	**1191**
	M	**0**	**0**	**53**	**36**	**76**	**152**	**134**	**124**	**23**	**0**	**21**	**26**	**645**
	S	**0**	**0**	**6326**	**3386**	**11578**	**21037**	**24095**	**15220**	**6604**	**0**	**98**	**2**	**88346**

Survey Type		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Crew HQ: CSO-Chicago South CH														
SA_BARE_ST - BARE STEEL SURVEY	W	0	0	11	3	15	54	31	8	16	0	0	0	138
	M	0	0	0	0	0	1	1	0	0	0	0	0	3
	S	0	0	97	18	110	912	377	64	219	0	0	0	1797
SA_BT - BRIDGE AND TUNNEL SURVEY	W	0	0	1	0	0	1	0	0	1	0	0	1	4
	M	0	0	0	0	0	0	0	0	0	0	0	0	2
	S	0	0	0	0	0	0	0	0	0	0	0	0	0
SA_BUS_LK - BUSCIMP MAIN SVC SURVEY	W	0	0	15	7	55	96	85	18	59	0	0	0	335
	M	0	0	9	3	24	48	54	7	24	0	0	0	168
	S	0	0	480	109	756	1382	1898	129	1012	0	0	0	5766
SA_EXP_PIP - RES EXPOSED PIPING SURVEY	W	0	0	18	8	39	57	52	13	39	0	0	0	226
	M	0	0	0	0	1	1	1	0	1	0	0	0	5
	S	0	0	3346	2089	6103	7731	5363	1476	2049	0	0	0	28157
SA_GATE_SN - GATE STATION	W	0	0	1	0	0	1	0	0	2	0	0	1	5
	M	0	0	0	0	0	0	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	0	0	0	0	0	0	0
SA_HP_M_S - PGL HP MAIN SVC SURVEY	W	0	0	67	0	0	65	0	0	65	0	1	64	262
	M	0	0	25	0	0	24	0	0	24	0	0	24	99
	S	0	0	3	0	0	3	0	0	3	0	0	3	12
SA_MP_SN - MP STATION	W	0	0	3	0	0	3	0	0	3	0	0	3	12
	M	0	0	0	0	0	0	0	0	0	0	0	0	2
	S	0	0	0	0	0	0	0	0	0	0	0	0	0
SA_RES_LK - RES MAIN SVC SURVEY	W	0	0	3	4	19	16	34	6	15	0	0	0	97
	M	0	0	6	9	46	30	56	14	28	0	0	0	188
	S	0	0	1112	1388	5171	5364	7193	2295	3410	0	0	0	25933
Totals:	**W**	**0**	**0**	**119**	**22**	**128**	**293**	**202**	**45**	**200**	**0**	**1**	**69**	**1079**
	M	**0**	**0**	**42**	**12**	**70**	**106**	**112**	**21**	**78**	**0**	**0**	**25**	**466**
	S	**0**	**0**	**5038**	**3604**	**12140**	**15392**	**14831**	**3964**	**6693**	**0**	**0**	**3**	**61665**
Reports Total:	**W**	**0**	**0**	**377**	**112**	**419**	**798**	**645**	**428**	**431**	**97**	**2**	**226**	**3535**
	M	**0**	**0**	**153**	**114**	**237**	**370**	**414**	**241**	**190**	**82**	**21**	**89**	**1910**
	S	**0**	**0**	**14517**	**11543**	**35969**	**46076**	**54611**	**30930**	**30871**	**1827**	**98**	**11**	**226453**

REQUEST NO. AG 7.08:

Re: PGL response to data request AG 4.12(j)(iv) (originally mis-labeled by PGL as response to data request AG 4.12(i)(iv)).

Please identify the percentage of PGL's system covered by each leak survey each year 2010-2015, or else please explain in detail why PGL does not track information as to how much of its distribution system is covered by each leak survey.

RESPONSE:

In accordance with Peoples Gas' Leak Survey Manual and PHMSA guidelines, all of Peoples Gas' distribution system is covered by leak survey. Peoples Gas does not track how much of its distribution system is covered each year because the surveys are broken down by type and frequency, so each type of survey is tracked to completion not by percentage of the distribution system.

Person(s) Responsible:

Mark Kinzle -- Director, Gas Operations Planning

REQUEST NO. AG 7.09:

Re: PGL response to data request AG 4.12(j)(v) (originally mis-labeled by PGL as response to data request AG 4.12(i)(v)).

Please state the numbers of leaks found by year (2010-2015) for each leak survey type, or else please explain in detail why PGL does not track the number of leaks found each time it conducts a leak survey.

RESPONSE:

Peoples Gas does have historical data on leaks found by leak surveys; however, Peoples Gas does not, in the ordinary course of business, track the number of leaks found each year by leak survey type.

Person(s) Responsible:

Mark Kinzle -- Director, Gas Operations Planning

REQUEST NO. AG 11.09:

Please refer to the Company's Response to data request AG 4.14(i) (supplemental), and respond to the following:

a. For the years 2010 to 2016, please discuss in detail, separately for each year, the numbers, types and frequency of leak surveys performed each year on the Company's distribution system.
b. In any year from 2010 to 2016, did the Company perform leak surveys more frequently than the minimums required by its Operations and Maintenance manuals? If so, please identify in what years surveys were more frequent.
c. In any year from 2010 to 2016, did the Company cover a greater percentage of its distribution system with surveys than the minimum amount required by its Operations and Maintenance manuals on an annual basis? If so, please identify those years.

RESPONSE:

a. Peoples Gas objects to this request as unduly burdensome to the extent it requests data prior 2015, as those records are not readily available and analysis would be required to extract the requested information. For 2016, 1,926 miles of main and 244,978 services have been surveyed as of October 3, 2016. In 2015, 1,910 miles of main and 226,453 services were surveyed.

The list below outlines the types of leak surveys, along with their respective frequencies over the requested period:

Mains
1. High Pressure and Transmission Lines – 4 times annually
2. Business Districts - annually, not exceeding 15 months
3. Loop - 3 times annually
4. Medium Pressure, residential, cast iron / ductile iron mains - annually
5. Medium Pressure, Low Pressure, residential, I – every 5 calendar years, not exceeding 63 months
6. Non-Corrosion Protected Steel – every 3 calendar years, not exceeding 39 months

Service Pipes
1. Loop - 3 times annually
2. Business District - annually, not exceeding 15 months
3. Residential – every 5 calendar years, not exceeding 63 months
4. Non Corrosion Protected Metallic Service Pipes (except cast iron / ductile iron (CI/DI)) – every 3 calendar years, not exceeding 39 months
5. Cast iron / ductile iron Medium Pressure – annually, not exceeding 15 months
6. High Pressure and Transmission System - 4 times annually

b. For the years for which leak survey data is readily available, 2015 and 2016, leak surveys were not performed more frequently than required by the Operations and Maintenance manual.

c. There is not an annual requirement in the Operations and Maintenance manual to survey a certain percentage of the distribution system for leaks.

Person(s) Responsible:

Mark Kinzle -- Director, Gas Distribution Planning

Tom Webb -- Manager, Compliance

REQUEST NO. AG 11.17:

Please reference the Company's response to data request AG 4.12(c), and answer the following:

a. How many years were used in HDD weather normalization?
b. Are there any PHSMA requirements that require the Company to evaluate leaks on a weather-normalized basis? If so, provide a copy of the requirement.
c. Please describe the Company's logic for using HDD to weather normalize compared to other weather metrics. In particular, please explain how the Company's approach that accounts for weather variables that influence ground-penetrating freezing temperatures such as amount of snow cover (insulation), soil type (moisture content), and consecutive days below freezing.
d. In what year did the Company begin to weather normalize leak data using HDDs?

RESPONSE:

a. HDD weather normalization was performed using 12 years of actual weather data.
b. No.
c. The use of HDD was the most feasible approach for weather normalizing the leak data. The other weather metrics listed are unavailable.
d. 2015.

Person(s) Responsible:

Mark Kinzle -- Director, Gas Operations Planning

REQUEST NO. AG 11.10:

For *each* type of main in the Company's distribution system (bare steel, coated steel, cast iron, ductile iron, plastic, etc.), please provide leaks actually found (not weather-normalized) per mile for each year from 2010 – 2015 in a working Excel spreadsheet format, including all data used to make the calculations, and leak data separated by classification.

RESPONSE:

Due to the difficulty in identifying the source of an underground leak, the facility (main or service) and material type can only be accurately determined when the leak has been repaired and cleared (which is supplied in the response to request AG 11.13), not upon finding the leak. Data for total leaks found for each year from 2010-2015 is supplied in the response to request AG 11.15.

Person(s) Responsible:

Mark Kinzle -- Director, Gas Distribution Planning

REQUEST NO. AG 11.11:

Please provide the cracks & breaks (not weather normalized) per mile for cast iron and ductile iron mains by pipe diameter from 2010 – 2015 in a working Excel spreadsheet format, including all data used to make the calculations. If the Company does not have these figures, please explain in detail what metric the Company uses to monitor these types of leaks on cast and ductile iron and provide copies of these metrics in working Excel files with supporting data for 2010 - 2015.

RESPONSE:

For 2014-2015, please see **AG 11.11 Attach 01.** For 2010-2013, the data necessary to complete the requested calculations is not readily accessible.

Person(s) Responsible:

Mark Kinzle -- Director, Gas Distribution Planning

REQUEST NO. AG 11.12:

For *each* type of service in the Company's distribution system (bare steel, coated steel, cast iron, ductile iron, plastic, etc.), please provide leaks actually found (not weather-normalized) per 1000 services for each year from 2010 – 2015 in a working Excel spreadsheet format, including all data used to make the calculations, and leak data separated by classification.

RESPONSE:

Due to the difficulty in identifying the source of an underground leak, the facility (main or service) and material type can only be accurately determined when the leak has been repaired and cleared (**see AG 11.14 Attach 01**), not upon finding the leak. Data for total leaks found for each year from 2010-2015 (**see AG 11.15 Attach 01**).

Person(s) Responsible:

Mark Kinzle -- Director, Gas Distribution Planning

REQUEST NO. AG 11.13:

For *each* type of main in the Company's distribution system (bare steel, coated steel, cast iron, ductile iron, plastic, etc.), please provide leaks repaired (not weather-normalized) per mile for each year from 2010 – 2015 in a working Excel spreadsheet format, including all data used to make the calculations, and leak data separated by classification.

RESPONSE:

Please see **AG 11.13 Attach 01.**

Person(s) Responsible:

Mark Kinzle -- Director, Gas Distribution Planning

REQUEST NO. AG 11.14:

For *each* type of service in the Company's distribution system (bare steel, coated steel, cast iron, ductile iron, plastic, etc.), please provide leaks repaired (not weather-normalized) per 1000 services for each year from 2010 – 2015 in a working Excel spreadsheet format, including all data used to make the calculations, and leak data separated by classification.

RESPONSE:

Please see **AG 11.14 Attach 01.**

Person(s) Responsible:

Mark Kinzle -- Director, Gas Distribution Planning

REQUEST NO. ENG 1.01:

Please provide the report referenced on p. 20 of PGL Ex. 1.0, Keifner and Associates, Inc. (March 1, 2007) "Review of the Peoples Gas Light and Coke Company Iron Gas Main Replacement Program," Final Report No. 07-23.

RESPONSE:

Please refer to ENG 1.01 Attach 01 for the report identified in the above question.

Person(s) Responsible:

Juan Santiago -- Manager, Gas Distribution Design

Kiefner & Associates, Inc.

March 1, 2007

Mr. Bradley Haas
The People's Gas Light and Coke Company
130 East. Randolph Drive
Chicago, IL 60601

Dear Mr. Haas,

Enclosed are three copies of our final report entitled "REVIEW OF THE PEOPLES GAS LIGHT & COKE COMPANY CAST IRON GAS MAIN REPLACEMENT PROGRAM."

If you need anything further, please call.

Sincerely,

Nicholas D. Ashcraft
Senior Pipeline Specialist

NDA:ts
Enclosures

585 Scherers Court
Worthington, Ohio 43085
www.kiefner.com
Phone (614) 888-8220
Fax (614) 888-7323

07-23

Review of The Peoples Gas Light & Coke Company Cast Iron Gas Main Replacement Program

Final Report No. 07-23

FINAL REPORT

on

Review of The Peoples Gas Light & Coke Company Cast Iron Gas Main Replacement Program

to

Peoples Gas Light & Coke Company

March 1, 2007

by

Carolyn Kolovich, Nick Ashcraft, John Kiefner and Jesse Mitchell

KIEFNER AND ASSOCIATES, INC.
585 Scherers Court
Worthington, Ohio 43085

0456-0601

TABLE OF CONTENTS

Tables

TABLE OF CONTENTS
Tables (continued)

Page

Figures

Review of The Peoples Gas Light & Coke Company
Cast Iron Gas Main Replacement Program
to
Peoples Gas Light & Coke Company
by
Carolyn Kolovich, Nick Ashcraft, John Kiefner and Jesse Mitchell

EXECUTIVE SUMMARY

This report presents the results of a review and assessment of Peoples Gas Light & Coke Company's (PGL) Cast Iron (CI) and Ductile Iron (DI) Replacement Program. The review and assessment suggest that the CI and DI main replacement program currently being carried out by PGL is working effectively in that the pipe is being replaced at a reasonable average rate and the numbers of breaks and cracks are declining. Of the 3,450 miles of CI and DI mains present in 1981, 1,978 miles remained at the end of 2006. The 1,472 miles of mains retired from 1981 through 2006 (a period of 26 years) amounts to an average rate of replacement of 56.62 miles per year.

The methods used by PGL to select segments for replacement consist of:

- Main Ranking Index (MRI) score of 6 or higher
- Coordination with city-wide infrastructure modifications
- Selection typically based on planned upgrading work

These methods appear to be working well. The MRI scoring model has effectively prioritized the worst pipe segments for replacement as evidenced by the declining rates of breaks and cracks since its inception in 1993. The MRI scoring model also reveals that the majority of the pipe that remains in the system is performing reasonably well. Seventy percent of the remaining segments have MRI scores less than 1 and ninety percent have MRI scores less than 3.

By linear extrapolation of the trend in pipe replacement to date it is possible to predict a theoretical completion date of 2038. For the remaining 1,978 miles of pipe, this would require a replacement rate of 61.81 miles per year, a rate higher than the actual average rate achieved to date. However, the review and assessment indicate that a less aggressive overall replacement program could be carried out without compromising the safety and reliability of the system. It is shown herein that the larger-size pipe segments (16-inch and over) could be safely replaced at rates significantly lower than the actual average rate to date of 56.62 miles per year. A previous study (by Zinder Engineering, Inc) recommended that the completion date for replacement be set as 2050. Replacement by 2050 of all 1,978 miles of remaining pipe would require a replacement

rate of 44.95 miles per year. The review described in this report reveals that the larger-size pipe segments (16-inch and over) account for less than 2 percent of the pipe breaks and less than 1 percent of the cracks. The review further shows that residual portions of the 4-inch pipe (constituting less than 10 percent of the original 4-inch CI pipe mileage) that have not been characterized by high MRI scores, are causing very few on-going problems. Therefore, we believe that the schedule for replacement of the large-diameter segments and short residual segments of the smaller-diameter pipes that do not have high MRI scores could be extended significantly beyond 2050. Accordingly we are recommending the following:

- PGL should continue to employ the present MRI threshold score of 6 as one of their criteria for selecting segments for replacement. The declining rates of occurrences of breaks and cracks show that this is an effective criterion.
- Replacement of all segments of 4-inch, 6-inch, and 8-inch pipe should be completed by 2036 as these sizes of pipes have accounted for over 90 percent of the instances of breakage and cracking.
- Replacement of all segments of 10-inch and 12-inch pipe should be completed by 2050.
- Replacement of all segments of 16-inch and larger pipe should be completed by 2080.

We also recommend that the rate of replacement for each size to meet these goals be kept relatively constant until the amounts remaining are below 10 percent of the original mileage. If that is done, the rates of occurrences of breaks and cracks should continue to decline, and therefore, the operations and maintenance costs associated with the CI and DI mains would be expected to decline accordingly. The replacement costs per year will most likely be less under the recommended replacement scenario than they would be if all CI and DI pipe were to be phased out by the end of 2038. The replacement costs per year under the recommended scenario will be higher initially than they would be if the plan to phase out CI and DI mains by the end of 2050 were to be followed. However, the costs per year will decrease under the recommended scenario such that after 2036 they will be considerably less than they would be if the plan to phase out CI and DI mains by the end of 2050 were to be followed.

INTRODUCTION

Presented herein are the findings of our project to review and assess Peoples Gas Light & Coke Company's (PGL) Cast and Ductile Iron Gas Main Replacement Program. The objectives

of our project were to review the scope and status of the on-going replacement program, to assess whether or not the program as presently constituted is appropriate in terms of benefits and costs, and to make such recommendations as may be necessary to modify the program, its implementation, and/or its schedule of execution to assure that the remaining cast and ductile iron infrastructure will not adversely affect PGL's ability to provide natural gas service to its customers in a safe and reliable manner. This effort was carried out in response to the following mandate from the Illinois Commerce Commission as part of a merger order.

Peoples Gas will pay for the professional fees and costs of an independent outside consultant with appropriate experience and expertise to (i) conduct a study of Peoples Gas' cast and ductile iron main replacement program and (ii) make recommendations regarding appropriate improvements to the program and its implementation. In order to start the study as soon as possible, Peoples Gas with input from the Commission Staff will select the outside consultant and oversee the conduct of the study. The study shall: (1) assuming a consultant can be selected in a timely manner, be completed no later than March 1, 2007, so that it can be used in support of the rate case anticipated to be filed in early 2007 and discussed in Mr. Schott's direct testimony; (2) identify the main replacement criteria currently utilized by Peoples Gas (including the ZEI criteria resulting from the prior study commissioned by Peoples Gas); (3) determine how the existing replacement program criteria have been implemented by Peoples Gas; (4) determine the current status of the main replacement program; (5) recommend criteria for the replacement of cast and ductile iron main to be utilized on a going forward basis; (6) recommend a schedule for the replacement of cast and ductile iron main on a going forward basis; and (7) include an estimate of the costs for the replacement program based on the recommendations included in the study. A copy of the study, its recommendations and cost estimates shall be provided to the Commission's Director of the Energy Division upon completion.

PGL places great importance on its CI and DI replacement program. For example PGL spent more than $32,000,000 in capital cost replacements of CI and DI pipe in addition to nearly $6,000,000 in operations and maintenance cost in 2006 to retire 47.24 miles of this pipe. The status reports previously prepared by others contain recommended replacement schedules that imply that the program is eliminating cast iron at a rate that reasonably assures retirement of segments before they reach the end of their expected service life. Nevertheless, because of concerns regarding the effect of the replacement program on the ability of the company to deliver safe, reliable and cost-effective service to the customers, PGL retained Kiefner and Associates, Inc. to provide an independent review of the replacement program.

BACKGROUND

In January of 1979, a PGL task group published the report, "Long-Range Operating Plan for the Distribution Department" that recommended the replacement of cast iron pipe of certain sizes and quantities. In the following year, PGL retained Zinder Engineering, Inc. (ZEI) to review and evaluate their cast iron distribution system and submit recommendations for controlling the cast iron pipe failures. In May 1981, ZEI submitted its report which contained a proposed replacement program for approximately 1,510 miles of PGL's cast iron distribution pipe, especially the 4-inch and 6-inch-diameter segments that appeared to be prone to failure from corrosion. ZEI's suggested target date for completion of this program was 2030. PGL instituted a cast iron replacement program to deal with the approximately 3500 miles of cast iron pipe of various sizes in 1981 and has continued actively replacing segments at an average rate of about 56.6 miles per year.

In February 1994, ZEI, Inc. submitted a report on the status of the replacement (retirement) program and reevaluated the process. In this report, a modification to the program was recommended to conclude the retirement program in the year 2050. ZEI, Inc. conducted another program status review in 2002 and submitted recommendations for minor adjustments to the program and maintained the termination date in 2050.

The ZEI studies addressed and adequately answered the question: Why replace cast iron? The answers can be summarized as follows. Cast iron is brittle and relatively weak. The cast iron pipe was installed bare and cannot be protected by cathodic protection because of lack of dependable electrical continuity across the mechanical joints. ZEI developed the rationale that explains why cast iron pipe fails. The individual pieces of pipe are supported at their ends on blocks. Flexural stress is created by the weight of the soil overburden, by the weight of the pipe itself, and by forces from frost heave. Corrosion reduces its wall thickness and thus reduces its flexural resistance. Eventually, the cast iron pipe installed will fail as it is in a relatively corrosive environment.

Flexural resistance is directly related to the "section modulus", S, of the pipe which is a function of its actual outside diameter (OD), inside diameter (ID), and wall thickness, t where t is equal to (OD-ID)/2. The section modulus is a function of these parameters as follows.

$$S = \left(\frac{\left(OD^4 - ID^4\right)\left(\pi/64\right)}{OD/2} \right)$$

One can determine from this relationship, the relative flexural resistances of the various pipe sizes based on their actual dimensions. The relative section moduli for the sizes of pipe in PGL's system are shown in Column 2 of the table below. Note that these are relative values with the standard of comparison being the ratios of the moduli with that of 4-inch pipe being set arbitrarily at 1. Column 3 shows the altered flexural resistances for each size if each pipe sustains a uniform 360-degree metal loss of 0.2 inch, and Column 4 shows the percentage of change as a result.

Table 1. Flexural Resistance by Pipe Size

Pipe Size, inches	Relative Section Modulus	Relative Section Modulus After 0.2 inch Wall Loss	Percent Change as a Result of the Wall Loss
4	1.00	0.47	52.84
6	2.37	1.22	48.48
8	4.43	2.40	45.94
10	7.38	4.28	42.09
12	11.62	7.18	38.16
16	24.56	16.78	31.70
20	40.31	28.16	30.16
24	64.68	47.24	26.96
30	110.37	83.80	24.07
36	177.37	139.21	21.52
48	416.45	348.80	16.25

These calculations reveal the relative resistance by pipe size to breaks and cracks that result from the bending of the pipe and the occurrence of corrosion-caused metal loss. A 48-inch pipe has more than 400 times the flexural resistance of a 4-inch pipe. After a fixed amount of uniform metal loss of 0.2 inch, the flexural resistance of the 48-inch pipe is degraded by 16 percent while that of the 4-inch pipe is degraded by more than 50 percent. The relative flexural resistance of the 48-inch pipe corroded by that amount is then more than 700 times greater than the remaining flexural resistance of the 4-inch pipe. These considerations strongly suggest that the smaller-size pipes are far more susceptible to breakage than the larger-size pipes. As will be shown, the rates of breakage and cracking bear out this hypothesis.

ZEI also determined from a 1957 study of soil types and conditions by the National Bureau of Standards supplemented by measurements on samples of corroded pipes (coupons) that the median rate of metal loss after a period of time is predictable by means of the following relationship:

$$wl = 0.895(y)^{1.076}$$

where:

wl is the weight loss in ounces per square foot of surface area

y is the number of years the pipe has been in service

This relationship represents the average trend of rates of metal loss that vary widely from segment to segment; it is not sufficiently accurate to permit predictions of metal loss for specific segments of pipe unless it is adjusted for the specific conditions associated with those segments. Therefore, its use herein is intended only as a means to compare the effects of pipe size on remaining life.

What the equation means may be ascertained from the following example. Consider a 4-inch pipe that has an actual OD of 4.8 inches and an actual ID of 4.0 inches (wall thickness is 0.4 inch). Suppose one wants to estimate how long it would take to lose half of the wall thickness if the loss of thickness occurs uniformly around the circumference and along the length. The circumference of the pipe is 15.08 inches. The weight per foot is 18.74 lb/ft (488 lb/ft^3 assumed). Therefore a square foot segment of the pipe weighs 16*18.74*12/15.08 = 238.6 ounces. Loss of half the wall thickness (0.2 inch of metal or 119.3 ounces) over the one square-foot area would occur in a period of 94 years. Similarly, ZEI's equation predicts the following hypothetical times for all sizes to suffer loss of half of their wall thicknesses if the conditions were such that the average rate shown above applied.

Table 2. Time Required to Lose Half the Wall Thickness by Pipe Size

Pipe Size, inches	Wall Thickness, inches	Time to Lose Half of Wall Thickness Uniformly, years	Relative Flexural Resistance with Half Wall Loss
4	0.40	94	0.47
6	0.43	103	1.14
8	0.45	109	2.15
10	0.49	118	3.59
12	0.54	130	5.67
16	0.65	155	12.02
20	0.68	163	19.80
24	0.76	181	31.80
30	0.85	201	54.36
36	0.95	223	87.46
48	1.26	290	205.36

The significance of these calculations is as follows. The results indicate the relative times by pipe diameter for half of the wall thickness to disappear. If half the wall thickness disappears uniformly, the section modulus of the pipe is roughly cut in half. However, it is clear that the effect on the relative flexural resistance remaining is much greater for small-size pipes (4 and 6-inch) than for the larger-size pipes. These comparisons further indicate the relative vulnerability of the smaller-size pipes to flexural failures, and they illustrate why the larger-size pipes regardless of their age to date exhibit relatively few breaks and cracks. This point will be revisited in the analysis of the effectiveness of the cast iron replacement program.

ZEI's study addressed the relative significance of pipe age on its failure rate, and suggested a prioritization rate keyed to pipe vintage while recognizing that the smaller size pipes should have the highest priority. By the time of ZEI's most recent review of the replacement program (2002), PGL had in fact been using, since 1993, a risk-based model to identify the "highest-vulnerability" segments for replacement each year. The risk-based model was called the "Main Ranking Index" or MRI. ZEI's 2002 report presented data in terms of declines in breaks and cracks after 1993 that suggested that the MRI may be effective for identifying highly vulnerable pipe segments. One of our objectives was to provide an independent assessment of the effectiveness of the MRI. That and other goals sought by PGL led to our carrying out the project described in this report.

CAST IRON AND DUCTILE IRON REPLACEMENT CRITERIA

PGL's Cast Iron (CI) and Ductile Iron (DI) Replacement Program is committed to retiring 45 miles of CI and DI pipe per year based on ZEI's recommended completion date of 2050. Three criteria are used to determine the pipe to be replaced in any given year. PGL's selections for replacement are coordinated with infrastructure improvements being undertaken by the city of Chicago, and other applicable municipalities. In addition to this, replacement miles are determined from each district's (North, Central and South) capital projects for the year by their subject matter experts based on criteria including conversions from low-pressure to medium-pressure service and general system improvements.

The other criterion is based on the Main Ranking Index (MRI) calculation that highlights the most problematic segments of pipe in terms of their maintenance histories. A segment of

pipe is defined by its age, size, material, pressure, length and location. PGL's detailed description of the MRI is included in Appendix A, and it is summarized herein.

The MRI takes into account five "break equivalents" for a given segment of pipe: the break equivalent based on breaks (B), the break equivalent based on cracks (C), the break equivalent based on visual observations (VPE), the break equivalent based on a coupon analysis (KU) and the break equivalent based on the repairs (RE) made for each segment where

$$MRI = B + C + VPE + KU + RE.$$

A break is defined as 100% circumferential separation of the pipe. Usually this results from a combination of downward pressure on the span from frost heave and loss of cross section of the pipe due to corrosion. In the MRI score of the break equivalent for breaks (B), at least a one-to-one relationship exists for this criteria, meaning 2 breaks would result in an MRI score equal to 2 for a low pressure main in a residential street with $< 50\%$ paving from the main to a building and a factor to adjust main segment length to a per block basis. If the segment is medium or high pressure, laid in a commercial district with $\geq 50\%$ paving from main to building, factors greater than 1.0 are multiplied by the number of breaks. The break equivalent score in that case will be higher than the actual number of breaks.

A crack is defined as less than a 100% circumferential separation of the pipe. The number of cracks on any given segment also weighs heavily in the index score, where at a minimum a factor of 0.5 is applied to the number of cracks that occur. The score for the break equivalent for cracks (C) may increase by the same factors mentioned above (operating pressure, street classification and pavement coverage) for the break equivalent.

The VPE is based mainly on visual inspections of the main as well as data from a coupon analysis if it is available. Any exposed segment is given a classification of "good" or "poor" based on a set of defined criteria established by PGL. These criteria changed in 1989 but both the observations prior to this change and from 1990 to the present are accounted for in the index calculation.

Data on the thickness and weight of a coupon extracted from the segment are used to calculate the break equivalent for a coupon analysis (KU). The KU factor also takes into account the operating pressure, street classification and pavement coverage. For a segment that has had coupons extracted, the break equivalent is based on the remaining wall thickness and remaining weight from each coupon as compared to the allowable limits for the minimum tolerable wall

thickness, based on 2 feet of frost and a buried depth of 3.5 feet. The minimum wall thickness varies for a given diameter, material and the length of pipe between supporting blocks. The KU factor also takes into account the "good" and "poor" observations.

The final break equivalent based on the repairs for a segment (RE) is calculated from the number of leak repairs and the number of repairs other than leaks such as the sealing of a bell joint or the installation of a drip standpipe. The RE factor also takes into account the "good" and "poor" observations as well as the material, operating pressure, main size, street classification and pavement coverage.

The MRI score is calculated monthly and any segment with an MRI score greater than 6 is selected for replacement. The value of 6 as a threshold will become apparent in the analyses discussed below. The B and C break equivalents are the most important drivers in the calculation. Coupons can be a significant driver but only 1,642 have been acquired. Review of a sampling of the MRI scores for random segments shows that the majority of the time, the index score is driven by the number of breaks and cracks on a given segment.

REPLACEMENT PROGRAM CRITERIA IMPLEMENTATION

The above-described criteria and their implementation are shown in the following flowchart, Figure 1. PGL has a goal to replace 45 miles of CI and DI mains per year in order to meet the completion date of 2050 that was recommended by ZEI. Those segments with an MRI score greater than 6 are replaced. Each month a new MRI score is calculated for each segment and additional mains may be flagged for replacement. Recent years have shown that the segments with an MRI above 6 account for approximately 5% of the total mileage replaced in a given year.

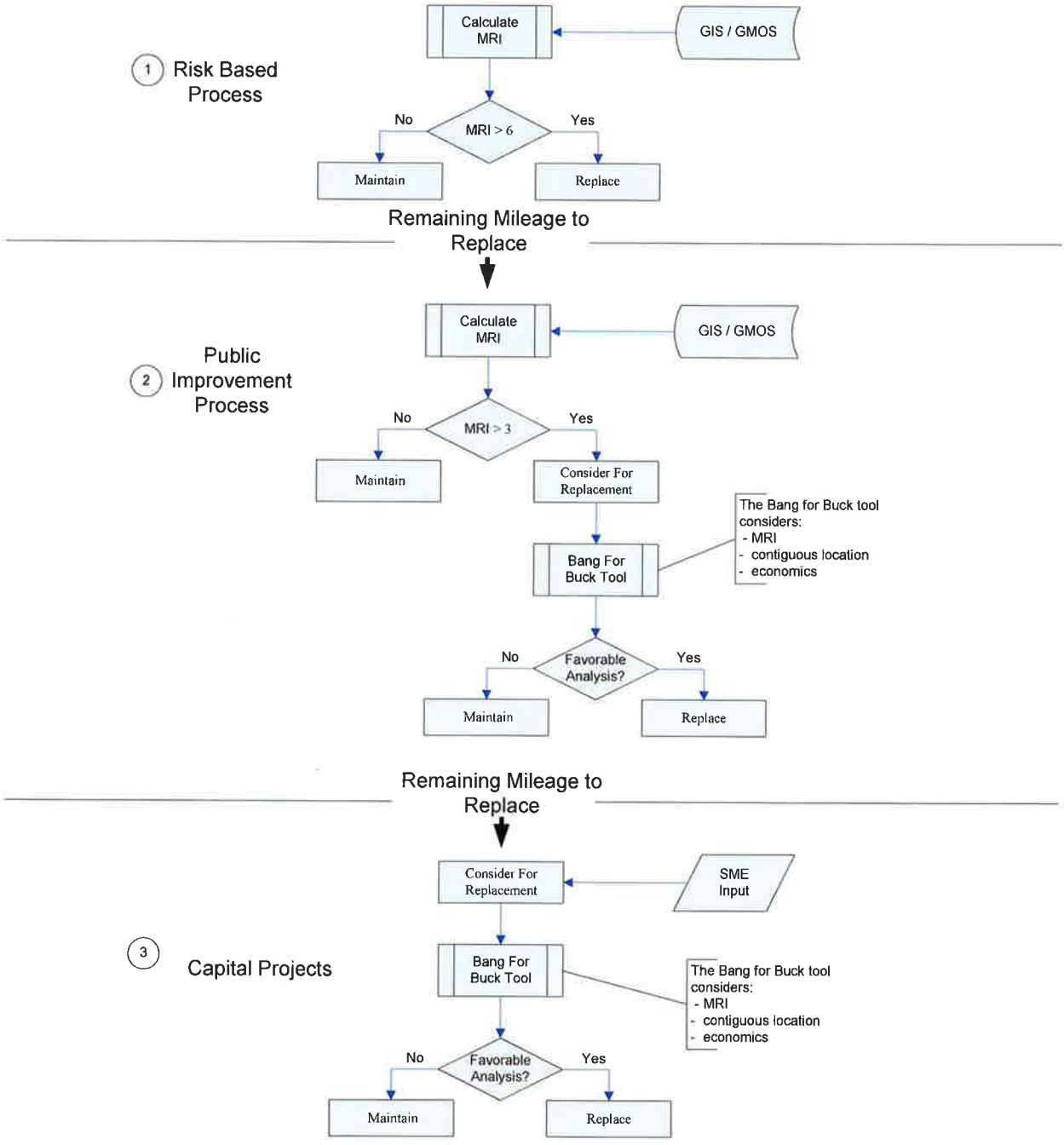


Figure 1. PGL Process to Determine Replacement Pipe

The remainder of the mains replaced in a given year is chosen by Steps 2 and 3 in Figure 1. Typically, the replacement completed in conjunction with public improvement projects accounts for approximately 35% of the total mileage replaced per year. In Step 2 any segments

with an MRI greater than 3 are considered for replacement during a city project. The rest of the miles replaced are determined by the subject matter experts (SMEs) in each district, and are typically based on system upgrading plans that include conversions from low-pressure to medium-pressure mains and general system improvements.

PGL implements a "Bang for the Buck" tool that incorporates spatial data (GIS) with their main frame database (GMOS). This is a useful tool in selecting pipe for replacement by combining all segment attribute information, including the MRI number, with things such as areas with a high maintenance cost, or areas that reduce the need for inside safety inspections. The tool yields results by looking at operations and maintenance costs and comparing those costs to costs of replacement. The ratios of these costs can be used to compare alternative projects. This approach maximizes the benefits of selecting a particular segment for replacement from both a safety and financial standpoint.

PGL's decision to use the MRI with a threshold value of 6 changed what was probably an adequate replacement program into one where not only are the replacements being accomplished, but the safety and reliability of the remaining segments are improving. This can be shown in a number of ways. First, there has been a significant reduction in the rates of breaks and cracks since the implementation of the MRI. The rate of occurrence of breaks and cracks was constant prior to the introduction of the MRI in 1993. This is shown in Figure 2 in terms of the flat trends in the numbers of breaks per mile and the number of cracks per mile between 1981 and 1992. In contrast, after 1992 as shown in Figure 2, both trends are distinctly downward. As seen in Figure 3 there is also downward trend in leaks per mile though it appears to have flattened out recently.

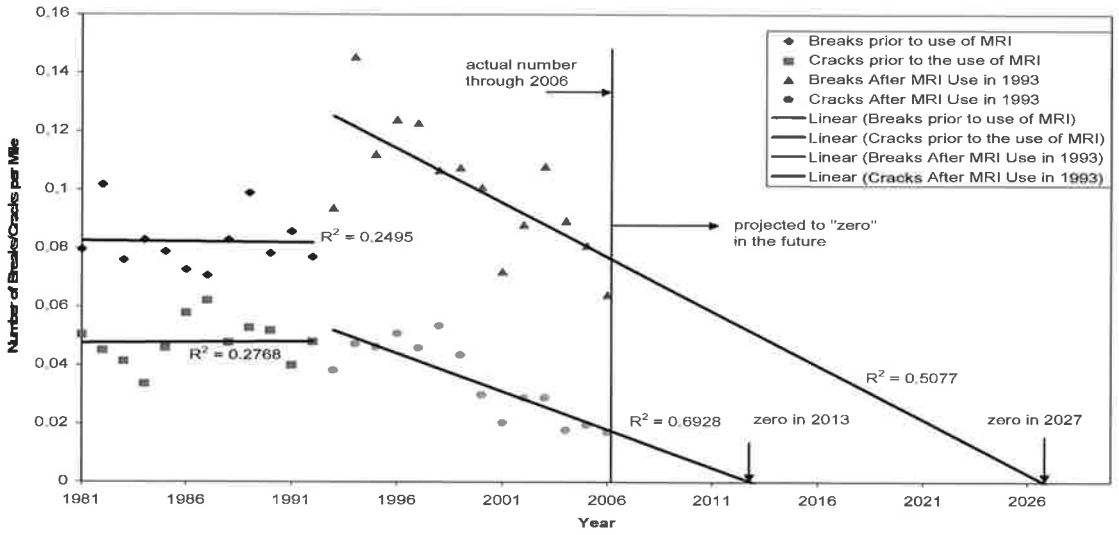


Figure 2. Break and Crack History

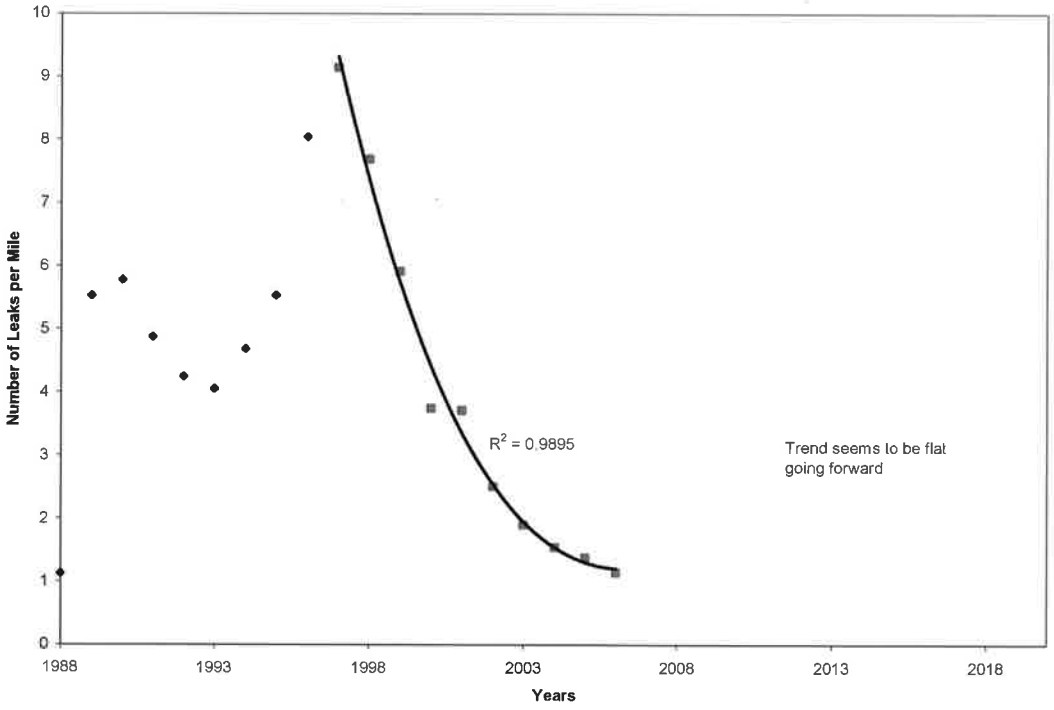


Figure 3. Leak History

Further evidence that the MRI is working can be seen in terms of the distribution of MRI scores for the segments that remain in service. The graph in Figure 4 shows that 70% of the

segments remaining in service have an MRI score of 1 or less and that over 90% have a score of 3 or less. Basically stated, most of the active segments do not have a maintenance history (i.e. they have not had any breaks or cracks).

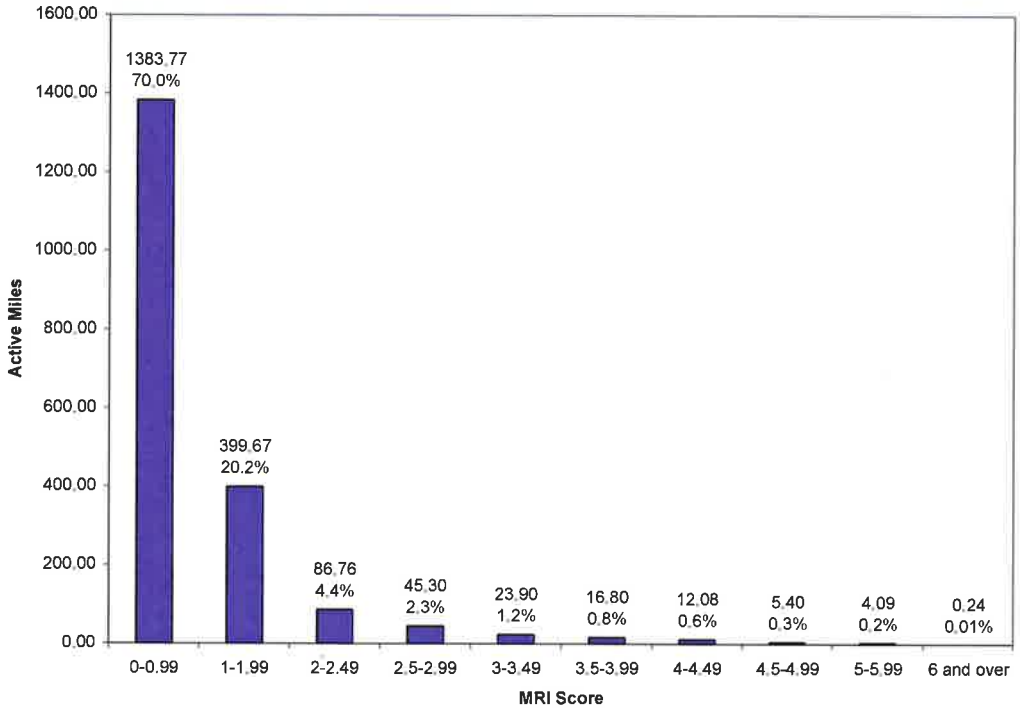


Figure 4. MRI Score of all Remaining Active Segments

It is logical to conclude that prioritizing replacements so as to remove segments with high MRI scores has resulted in the removal of the worst-condition segments. It is therefore reasonable to conclude that segments exhibiting MRI scores below 3 need not be given priority over segments that could be replaced economically on other bases.

One point should be kept in mind, however, and that is that the smallest sizes of pipe have been responsible for the majority of the breaks and cracks as can be seen in Figure 5 and Figure 6. These figures show the number of breaks and cracks by year by size, respectively. The numbers of breaks and cracks over the period from 1981 through 2006 are also summarized in the following table. As can be inferred from these numbers, the 4 and 6-inch segments have accounted for 92.7 percent of the breaks and 96.0 percent of the cracks.

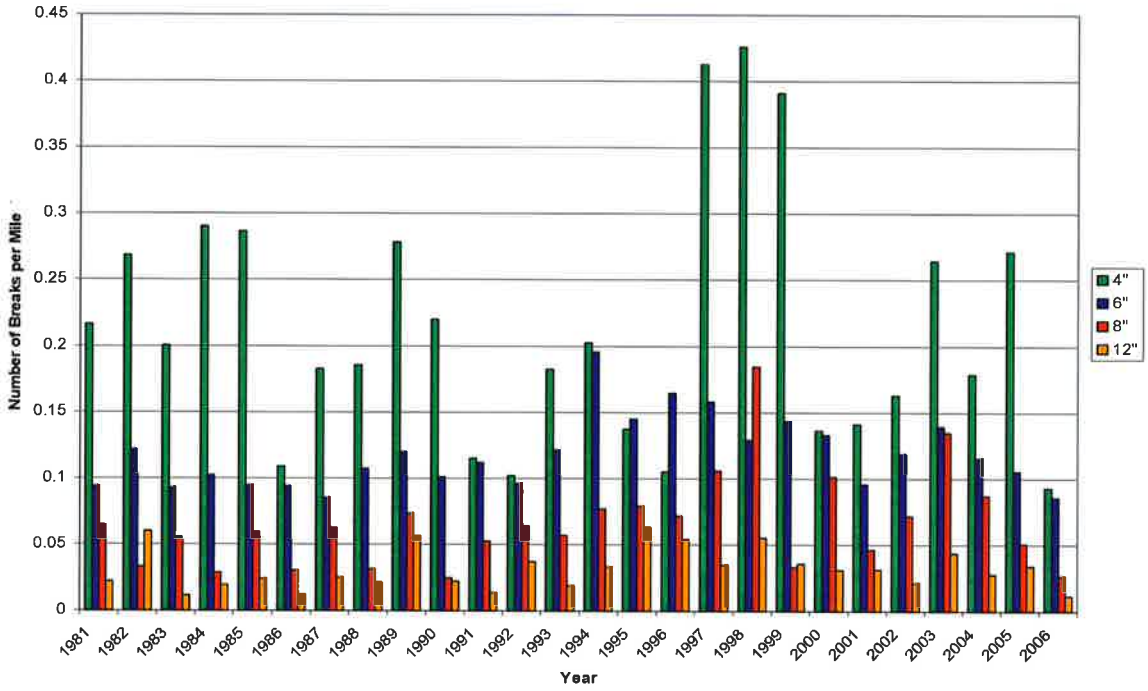


Figure 5. Breaks per Mile by Size of Main for 1981 – 2006

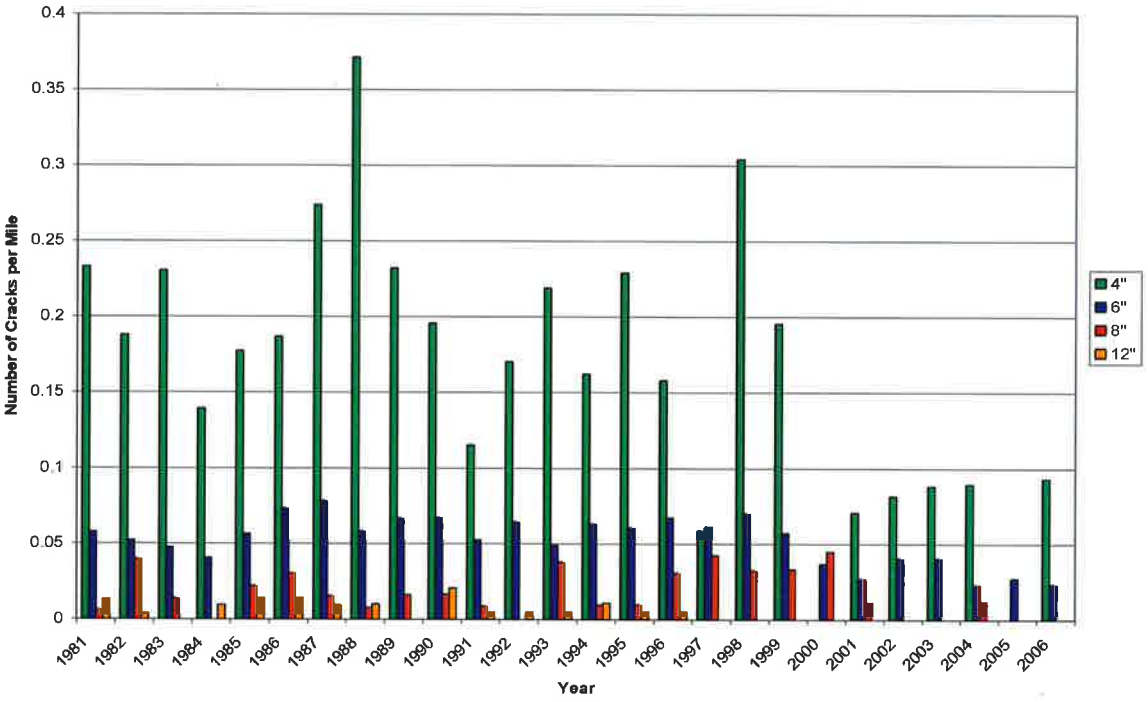


Figure 6. Cracks per Mile by Size of Main for 1981 – 2006

Table 3. Numbers of Breaks and Cracks by Pipe Size

Nominal Pipe Size	Number of Breaks	Number of Cracks	Miles in 1981	Miles Remaining	Percent Remaining
4	226	201	120.16	10.75	8.9
6	5535	2557	2423.76	1361.81	56.2
8	178	49	154.60	75.34	48.7
10	0	0	5.97	1.27	21.3
12	176	44	267.93	172.40	64.3
16	36	7	201.84	152.32	75.5
20	20	7	98.59	73.15	74.2
24	26	6	100.13	68.91	68.8
30	12	0	17.73	11.59	65.4
36	0	1	33.80	27.78	82.2
48	1	0	25.87	22.71	87.8
All	**6210**	**2872**	**3450.37**	**1978.04**	**57.3**

REPLACEMENT PROGRAM CURRENT STATUS

The progress of the replacement program is shown in Figure 7. Approximately 1,978 miles of CI and DI pipe remain as of the end of 2006. Figure 8 depicts the mileage of pipe that has been retired each year by size. Over the 26-year period from 1981 through 2006 approximately 56.6 miles of pipe have been replaced per year. Most of the retired mileage has involved the 6-inch segments, but that is not surprising because 6-inch pipe is by far the most commonly-occurring size in the PGL system. Through the late 80s and early 90s a large amount of the 4-inch main was replaced such that only 10.75 miles of that size remain out of the 120.16 miles that existed in 1981.

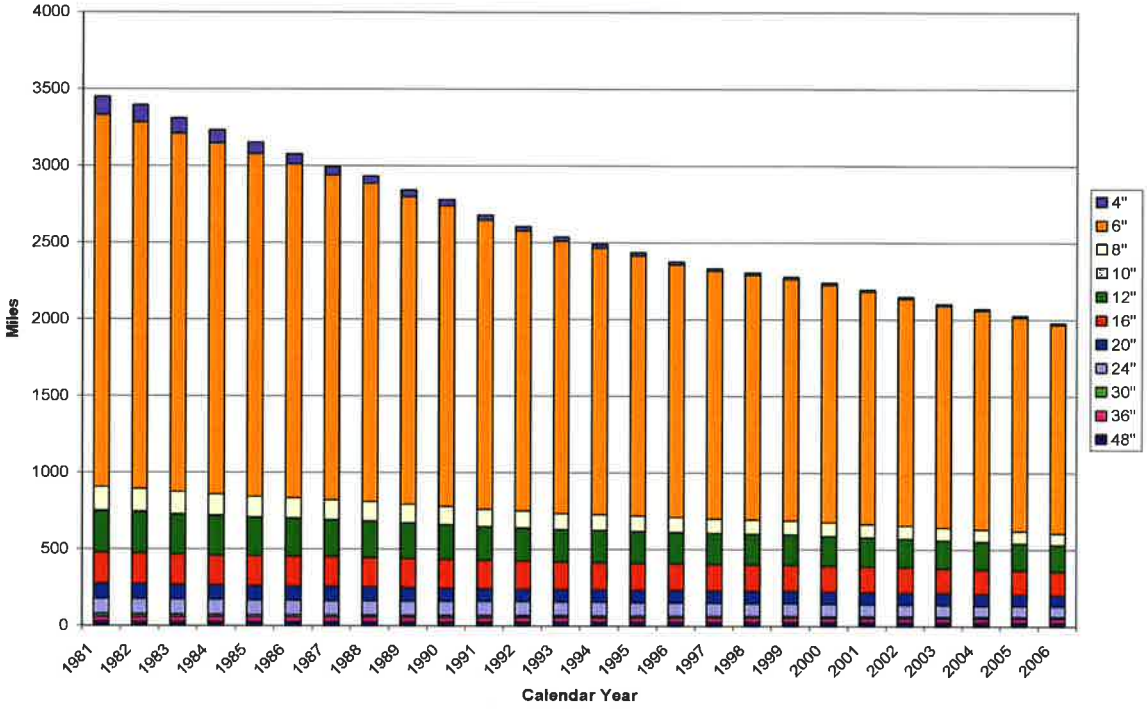


Figure 7. Miles of Cast Iron and Ductile Iron Remaining

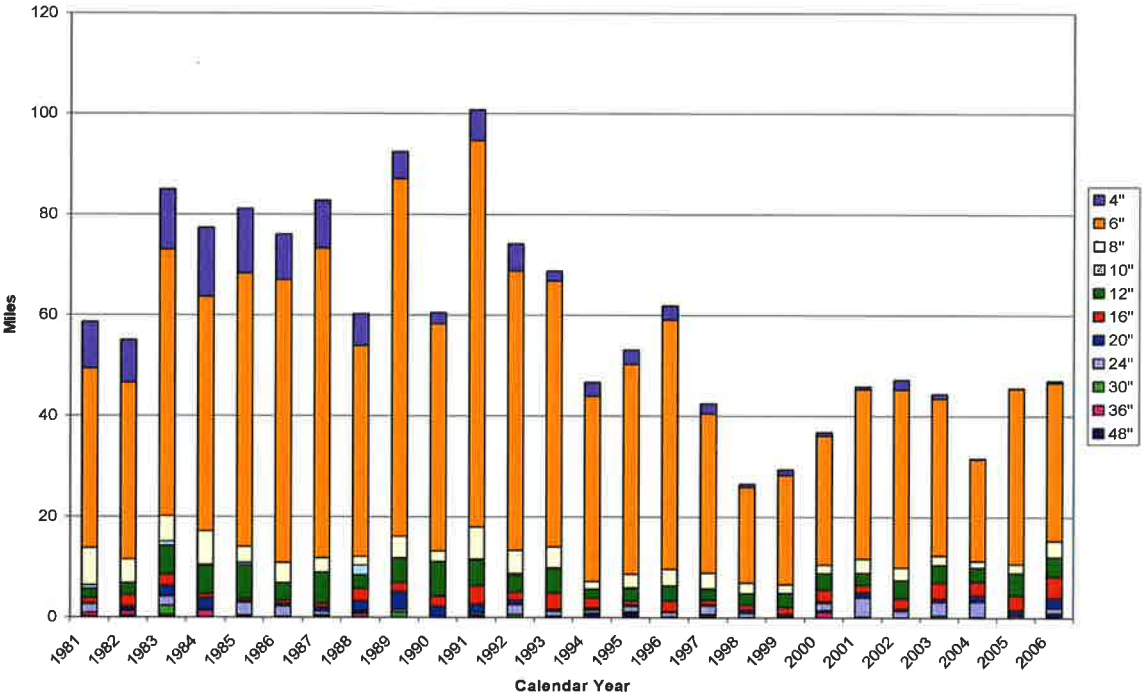


Figure 8. Miles of Cast Iron and Ductile Iron Replaced

This general trend with respect to replacement of all CI and DI mains can be projected linearly such that one can infer that all CI and DI pipe will be replaced by 2038. However, this is not the case when we look at the replacement trends of individual sizes of pipe. The graphs to determine the forecast dates are included in Appendix B and summarized in the table below.

Table 4. Forecast Dates for Completion of Replacement by Pipe Size Based on Trends Established from 1981 Through 2006

Nominal Pipe Size	Miles in 1981	Miles Remaining at End of 2006	Miles Retired	Percent Complete	Type of Trend	R^2	Forecast Year of Completion
4	120.16	10.75	109.41	91.1	polynomial	0.998	2015
6	2423.76	1361.81	1061.95	43.8	linear	0.978	2036
8	154.6	75.34	79.26	51.3	linear	0.980	2028
10	5.97	1.27	4.70	78.7	polynomial	0.975	*
12	267.93	172.4	95.53	35.7	linear	0.981	2052
16	201.84	152.32	49.52	24.5	linear	0.987	2089
20	98.59	73.15	25.44	25.8	linear	0.927	2083
24	100.13	68.91	31.22	31.2	linear	0.965	2065
30	17.73	11.59	6.13	34.6	linear	0.920	2051
36	33.8	27.78	6.02	17.8	linear	0.900	2142
48	25.87	22.71	3.16	12.2	*	*	*
All Sizes	**3450.37**	**1978.04**	**1472.33**	**42.7**	**linear**	**0.977**	**2038**

The R^2 values indicate the degree of correlation of the assumed trend with the actual data. An R^2 value of 1 represents a perfect correlation; an R^2 value of 0 represents no correlation. Values above 0.5 are often viewed as indicating at least a weak correlation. Values of 0.9 and above indicate very good correlations. That being the case, most of the correlations shown above are very good, and for that reason, the forecast completion dates are considered to be reasonably accurate. Where values are absent in the table, no trend was discernable from the data.

The forecast years for completion of replacement for pipe sizes 12-inch and smaller meet or nearly meet the target suggested by the most recent ZEI studies (i.e., completion by 2050). For the size above 12-inch, however, the completion dates range from 2051 to 2142. This does not mean that the replacement program is inadequate. In contrast, replacement of the smaller-size pipes which are by far the most vulnerable to failure by the target date of 2050 or before is virtually certain. As the relatively few instances of breaks and cracks occurring in the larger-size pipe shows, it would not be unreasonable to stretch out the replacement of those segments.